Marginal Fit of CEREC Crowns at Different Finish Line Curvatures

by

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

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ABSTRACT

INTRODUCTION: One important criterion for the long success of all-ceramic crowns is there marginal fit. The margin of a restoration is the interface between a restorative material and the tooth, and it is vital to the long-term success of the restoration. If marginal discrepancies are present, the luting material will be exposed to the oral environment, thus leading to a more aggressive rate or cement dissolution. As a result, the cement seal becomes weak and allows the percolation of bacteria.

PURPOSE: To compare the effect of a 0°, 45°, and 90° curvature of the abutment finish line on the marginal fit utilizing Vitablocs Mark II.

MATERIALS AND METHODS: Three #4 dentoform ivorine teeth, with different interproximal margins, (0°, 45°, 90°), were prepared for a full coverage all ceramic crown (Vitablocs Mark II, A-3), in a standardized manner using established guidelines for Ivoclar Vivadent, Inc. manufacturer's recommendations. Each tooth was duplicated in Ni-Cr alloy for scan and crown design per type of preparation, using Omnicam, Sirona. One all-ceramic crown was prepared for each case using CEREC MC XL, Sirona. A seating index was fabricated to ensure that the crown remained fully seated on the die for measurement. The overall measurement of the crown/die was used to fabricate a seating jig. Interproximal marginal misfits (μm's) were recorded using the KH 7700 Hirox 3D Digital Scanner.

RESULTS: Results demonstrated the lowest marginal misfit in the Zero degree finish line angle and the 45-degree finish line exhibited the heights. The mean marginal misfit of the 0°, 45°, 90° crowns was 22.92 and the marginal misfit of each crown was 24.58, 24.90 and 19.41 respectively.

CONCLUSION: In this pilot study the 45 and 90-degree interproximal marginal abutment finish line curvatures resulted in greater misfit in all ceramic CAD/CAM crowns. The next step will be to perform the study using a sample size of eight specimens per group. ANOVA statistical analysis will be performed and the null hypothesis will be tested.

TABLE OF CONTENTS

LIST OF FIGURES

- All figures created by the thesis author

LIST OF ABBREVIATIONS

CAD/CAM………………………………… Computer Aided Design/Computer Aided Manufacturing

CEREC……………………………………… Ceramic Restorations

3-D…………………………………………Three dimensional

LED………………………………………..Light-emitting diode

INTRODUCTION

The use of all-ceramic materials for fixed restorations has become a key topic in aesthetically oriented dentistry. There physical and mechanical properties significantly differed from each other. To use all-ceramic systems efficaciously, the clinician must have a high level of knowledge both to maximize the esthetic result and to choose materials appropriately for structural longevity.

Vitablocs Mark II are Predominantly glass ceramics that can mimic the optical properties of enamel and dentin, with a high flexural strength of 150MPa. These materials are machinable and contain sanidine ($KAlSi_3O_8$) as a major crystalline phase within the glassy matrix. Is a hard material with a Vickers hardness of 569.3. It has less abrasive properties, attributed to the industrial sintering process as well as to the small particle size (4um) of this ceramic system. This material is recommended for anterior restorations.

One important criterion for the long success of all-ceramic crowns is there marginal fit. The margin of a restoration is the interface between a restorative material and the tooth, and it is vital to the long-term success of the restoration. The fit of a restoration can be defined best in terms of the "misfit" measured at various points between the restoration surface and the tooth. The perpendicular measurement form the internal surface of the crown margin to the axial wall of the preparation is called the internal gap, and the same measurement at the margin is called marginal gap.

If marginal discrepancies are present, the luting material will be exposed to the oral environment, thus leading to a more aggressive rate or cement dissolution caused by oral fluids and chemo-mechanical forces. As a result, the cement seal becomes weak and allows the percolation of bacteria. Micro-leakage in the oral cavity can cause inflammation of the vital pulp and caries. Poor marginal adaptation of crowns increases plaque retention and changes the composition of the sub-gingival micro-flora

The American Dental Association specifies that a dental restoration must fit its abutment within 50um. This requirement demands that CAD/CAM systems have a very accurate data collection technique, sufficient computing power to process and design complex restorations, and a very precise milling system. Integration of technologic advances has resulted in the introduction of more competent sophisticated systems.

This is an observational comparative pilot study to determine the effect of a 0°, 45°, and 90° curvature of the abutment Shoulder finish line on the marginal fit utilizing Vitablocs Mark II. Acceptable Marginal fit of the restoration will be 50um as specified by The American Dental Association. The null hypothesis is that there is no difference in the marginal fit of CAD/CAM crowns with increasing finish line curvature.

REVIEW OF THE LITERATURE

Dental Restoration Milling Machine History and Background

In 1980 Werner H. Mörmann anticipated the attraction of restoring posterior teeth with tooth colored materials. At that time direct posterior restorations were not recommended due to polymerization shrinkage, resulting in the formation of marginal gaps, and lack of abrasion resistance (Mörmann, The evolution of the CEREC system, 2006). This situation encouraged him to keep studying materials, and on the basis of his own in vitro and in vivo studies with pressed and heat-polymerized resin composite inlays, he had the new idea of tooth colored inlays inserted adhesively with resin-based composite as a luting agent (Mörmann, 2006).

Now if inlays could solve the problem, Mörmann wondered how a dentist would be able to produce inlays quickly at the dental chair while the patient waits (Mörmann, The evolution of the CEREC system, 2006). This question encouraged him to visit his friend Dr. Marco Brandestini, who gave him the idea of optically scanning a tooth preparation, and asked him, "How accurately do these inlays actually have to fit?" (Mörmann, The evolution of the CEREC system, 2006). Through his investigations, Mörmann knew that a resin composite luting agent could seal margins up to 500 micrometers wide and be resistant to penetration (Bindl & Mörmann, 2003; Mörmann, 2006). Theoretically, 50 to 100 mm fitting accuracy in vitro appeared to be achievable (Mörmann, 2006).

After complex, expensive and none successful ideas introduced by Young and Altschuler on how to use optical instrumentation to develop an intraoral grid-surface mapping system in 1977 and the Duret system introduced in 1984 by Duret to generate single unit, full coverage restorations, the first Ceramic Reconstruction (CEREC) machine was developed in 1985 (Liu & Essig, 2008). It used a grinding wheel to fabricate the restoration, and the dentist had to create the occlusal area (Mörmann, The evolution of the CEREC system, 2006). This and other disadvantages brought the desire of new improvements in the system through a series of software and hardware upgrades, bringing significant changes (Fasbinder, 2010): the addition of a cylinder diamond, enabling the form-grinding of partial and full crowns (CEREC 2); the introduction of a two-bur-system with CEREC 3, and the "step bur" introduced in 2006 for high precision form-grinding (Mörmann, The evolution of the CEREC system, 2006); the separation of the milling chamber from the image-capture and design hardware; the change from a two-dimensional design program to a three dimensional (3-D) design with a 3-D software that substantially improved the understanding of the 3-D program; and speed and memory improvements (Fasbinder D. J., 25 years of chairside CAD/CAM dentistry, 2010). All these changes were made in less than 20 years. The most recent evolution that has been introduced is the light-emitting diode (LED) camera called the Blue-cam, which is based on a blue LED that replaces the infrared–emitting camera (Fasbinder D. J., 25 years of chairside CAD/CAM dentistry, 2010).

The evolution of the CEREC system has improved the scanning and milling process of ceramic materials as time has passed. The computer-aided design/computer-

aided manufacturing (CAD/CAM) system represents a new digital technology that can be used for in-office and laboratory made restorations utilizing esthetic materials. (Fasbinder D. J., 25 years of chairside CAD/CAM dentistry, 2010). The material will give the clinical outcome of the restoration (Fasbinder D. J., Chairside CAD/CAM: An Overview of Restorative Material Options, 2012).

All-Ceramic Restorative Materials

Ceramic materials can mimic the appearance of natural teeth and many different ceramic systems have been introduced for all types of indirect restorations. Ceramics are nonmetallic inorganic materials, including borides, carbides, metal oxides and nitrides, as well as complex mixtures of these materials. These materials can be strong and also very brittle, causing a failure after minor flexure. In other words, these materials are strong in compression, but weak in tension (Giordano & McLaren, 2010). In addition, some ceramic materials can be considered to be composites (i.e., their composition is made of two or more entities). Highly esthetic dental ceramics have high glass content, and higher-strength substructure ceramics generally are crystalline. The history of the development of substructure ceramics involves an increase in crystalline content ranging from 55 percent crystalline to fully polycrystalline (Kelly J. , 2008).

The ceramic material can be very translucent to very opaque in appearance (Giordano & McLaren, 2010). It has been concluded that the stronger and tougher ceramic materials are, the more opaque and less esthetic they become when compared to porcelains (Della Bona & Kelly, 2008; Kelly J. R., 2004). Also, ceramic specimens that have been polished can be expected to have much higher strength than unpolished prostheses fabricated from the same materials.

To gain understanding of the ceramic materials, different authors classified them in different ways. Dr. Russell Giordano and Dr. Edward A. McLaren in their overview of dental ceramics classified these materials by microstructure components (glass

composition and type crystalline phase), and processing methods (powder/liquid, pressed, or machined), to help in the understanding of their properties and uses. (Giordano & McLaren, 2010)

Dr. J. Robert Kelly, in his article "Dental ceramics, What is this stuff anyway?" (2004) classified all dental ceramic materials into one of three categories (Kelly J. , 2008; Kelly J. R., 2004; Denry, 1996):

Predominantly glass: The most esthetic; includes feldspathic materials, leucite-reinforced materials, and CEREC blocks (Kelly J. , 2008).

Particle-filled glass (predominantly structural): Includes lithium disilicate (E.max Press, E.max Cad, and Vita Blue Blocks) (Kelly J. , 2008).

Polycrystalline materials (no glass content and predominantly structural): Includes aluminum oxide and zirconium oxide (Kelly J. , 2008).

Developments in ceramic material science have led to improvements in the physical properties of modern ceramics; and the evolution of the software and hardware for the CEREC system is mirrored by developments in the materials available (Fasbinder D. J., 25 years of chairside CAD/CAM dentistry, 2010).

Lithium Disilicate Material

IPS e.max Press (press-fit lithium disilicate) and IPS e.max CAD (milled ingots of lithium disilicate, with CAD/CAM, were introduced by Ivoclar Vivadent (Amherst, N.Y., USA) (Fasbinder, Dennison, Heys, & Neiva, 2010). These different presentations of the material were design to be used in a dental laboratory as a more translucent coping material, when compared to zirconia (Fasbinder D. J., 25 years of chairside CAD/CAM dentistry, 2010). It then became available in several translucencies and shades for use in esthetic full contour, chair side restorations (Fasbinder D. J., 25 years of chairside CAD/CAM dentistry, 2010), and is now recommended for anterior or posterior crowns, implant crowns, inlays, onlays or veneers (Fasbinder, Dennison, Heys, & Neiva, 2010).

The CAD/CAM process gives the opportunity to mill the crown from monolithic blocks of lithium disilicate, rather than the traditional laboratory process of fabricating a strong substructure veneered with weaker veneering porcelain. The milled lithium disilicate block must undergo a two-stage crystallization process before being cemented. The first crystallization process occurs before milling the material, and the second one after the crown has been milled to the desired form by means of CAD/CAM technology (Fasbinder, Dennison, Heys, & Neiva, 2010). The IPS e.max CAD has a flexural strength of 360 to 400 megapascals; this is approximately two and one half times greater than that of other monolithic ceramic blocks available for CAD/CAM chairside restorations (Giordanos, 2006; Fasbinder, Dennison, Heys, & Neiva, 2010). Fasbinder and colleagues (2010) have suggested that with the use of a good cement

material (self-etching and dual curing;), the occurrence of thermal sensitivity may be as low as 7.7 percent after six months and none after one year.

In a clinical study of 62 lithium disilicate CAD/CAM crowns placed in 43 patients, Fasbinder and colleagues (2010) reported no identified cases of crown fracture or surface chipping after two years of clinical service. This demonstrates the benefits from the improved physical properties of the IPS e.max lithium disilicate compared with early lithium disilicate material fabricated by means of a lost-wax and heat pressed technique, and then veneered with fluorapatite-based porcelain (Pjetursson, Sailer, Zwahlen, & Hammerle, 2007; Marquardt & Strub, 2006). In addition, in a two-year clinical study of 41 posterior restorations, Reich and colleagues (2010) evaluated the clinical performance of chairside-generated crowns over a preliminary time period of 24 months. Forty-one posterior crowns made of a machinable lithium disilicate ceramic for full-contour crowns were inserted in 34 patients using a chairside CAD/CAM technique. The crowns were evaluated at baseline and after 6, 12, and 24 months. After two years, one abutment exhibited secondary caries and two abutments received root canal treatment. Within the limited observation period, the crowns revealed clinically satisfactory results.

Guess and colleagues (2010) studied the fatigue behavior and reliability of CAD/CAM lithium disilicate all-ceramic crowns, as compared to hand-layered -veneered zirconia all-ceramic crowns. Crowns were cemented to aged (stored in distilled water at 37 degrees Celsius for at least 30 days), resin based composite dies with a self-curing

resin-based dental luting material. Then the specimens were mounted in a universal testing machine, and load to fracture was applied on the distobuccal cusp at a rate of 1mm/min using three different step – stress profiles until failure occurred. Failure was designated as a large chip or fracture through the crown. If no failures occurred at high loads (> 900 N), the test method was changed to staircase r ratio fatigue. Stress level probability curves and reliability were calculated. The results showed that CAD/CAM-fabricated monolithic lithium disilicate crowns demonstrated increased fatigue-resistance and mechanical stability, whereas hand-layered-veneered zirconia crowns exhibited a high susceptibility to mouth motion cyclic loading with early veneer failure.

Vita Mark II

Some studies intended to understand the reliability, fatigue, and wear resistance of Vitablocs Mark II have been performed. Reiss and Walther (2000) studied the clinical longevity of VMI and VMII inlays and onlays. In a private practice, they treated 299 patients with 1010 full-ceramic restorations within a period of 39 months. The inlays and onlays were manufactured using the Cerec technique, and were seated in one single appointment. Re-examination was conducted 9 to 12 years after the placement. According to the Kaplan-Meier analysis the probability of clinical survival decrease to 90%, after ten years and 84.9% after 11.8 years with no further loss by the final observation at 12 years. In a systematic review of 15 clinical studies made by Martin and Jedynakiewicz (1999) a comprehensive literature search was undertaken, spanning from the year of introduction of the technology -1986 to 1997. They calculated a mean success rate of 97.4% over a mean period of 4.2 years on restorations milled from VMII.

Charlton, Roberts and Tiba (2008) measured physical and mechanical properties of IPS Empress CAD, Vitablocs Mark II, and Paradigm. The physical and mechanical properties tested were hardness, flexural strength and modulus, fracture toughness and coefficient of thermal expansion. For each of the materials, 25 specimens were fabricated to test each property, except for coefficient of thermal expansion, where n=5. They found that Vitablocs Mark II was the hardest (Vickers hardness 569.3) of the three materials, but had the lowest flexure strength (94.08 Mpa), flexural modulus (8.65 Gpa), and fracture toughness (1.37 Mpa), while IPS Empress CAD had the highest of

these last three properties. With these results, they concluded that the three ceramic materials significantly differed in all of the properties measured.

Marginal Fit

The use of all-ceramic materials for fixed restorations has become a key topic in aesthetically-oriented dentistry. Recent progress in material technology and manufacturing procedures has extended the implications not only for inlays, but for single crown restorations. In addition to fracture resistance and aesthetics, marginal fit is one of the most important criteria for the long-term success of all-ceramic crowns. (Beschnidt & Strub, 1999)

The margin of a restoration is the interface between a restorative material and the tooth, and it is vital to the long term success of the restoration. It has been found that completely closed margins are unattainable clinically, and the space between the tooth and the restorative material is called marginal gap (Freedman, Quinn, & Sullivan, 2007). Holmes, Bayne, Holland, and Sulik, (1989) defined marginal gap as the perpendicular measurement from the internal surface of the casting to the margin wall of the preparation. A marginal gap of no more than 119 micrometers should be obtained in order for the restoration to be clinically acceptable; however, it is prudent to minimize the gap in order to decrease the chance of leakage and staining (Freedman, Quinn, & Sullivan, 2007).

If marginal discrepancies are present, the luting material will be exposed to the oral environment, thus leading to a more aggressive rate of cement dissolution caused by oral fluids and chemo-mechanical forces. As a result, the cement seal becomes weak and allows the percolation of bacteria (Beschnidt & Strub, 1999). This will compromise

the longevity of the tooth, increasing the risk of dental caries caused by the main causative agents: mutans streptococci and lactobacilli (Featherstone, 2000). In addition, marginal accuracy is a determining factor that can influence the periodontal status and long-term reliability of the restoration (Krasanaki, Pelekanos, Andreiotelli, Koutayas, & Eliades, 2012). In other in vivo studies, increased plaque index scores and reduced periodontal health were evident when large marginal discrepancies in fixed restorations were present (Beschnidt & Strub, 1999). Also, other researchers have found that poor marginal adaptation of crowns increases plaque retention and changes the composition of the subgingival microflora (Tao & Han, 2009).

Marginal gaps of inlays and onlays were a big concern with early CAD/CAM restorations, because in the beginning CEREC machines produced inlays with marginal gaps of up to 200 micrometers, particularly where sharp line angles were present in the preparation (Freedman, Quinn, & Sullivan, 2007). This has been significantly reduced with the development of newer software, imaging, and machining systems (Mormann & Bindl, 1996; Freedman, Quinn, & Sullivan, 2007). Utilizing light microscopy and digital imaging, Denissen, Dozić, van der Zel, and van Waas (2000) compared the marginal fit of Cicero, Cerec 2, and Procera ceramic onlays; the mean marginal gaps were 74 μm, 85 μm, and 68 μm, respectively. These results were considered to be within a clinically acceptable range.

As CAD/CAM crowns evolve, marginal fit continues to improve (Freedman, Quinn, & Sullivan, 2007). Bindl and Mörmann (2005) made a study comparing marginal

fit of indirect CAD/CAM ceramic crowns using scanning electron microscopy (SEM) at 120x magnification. They found that Procera (17 +/- 16 μm) and Decim (23 +/- 17 μm) had smaller marginal gaps when they where compared with Cerec In-Lab (43 +/-23 μm) and conventional heat-pressed (Empress II) (44 +/- 23 μm) ceramic crowns. However, they concluded that the marginal gap widths of CAD/CAM crowns were within the same range as conventional all-ceramic crowns. (Freedman, Quinn, & Sullivan, 2007) Even though all of the marginal gap measurements may fall within a clinically acceptable range, variations in study design have made it difficult to directly compare the results of different studies.

Marginal Fit Measurements

Evaluation of the marginal discrepancy of the crowns may be influenced by several factors: the use or non-use of cement, the type of cement used storage time and treatment after cementation (e.g., thermocycling or cyclic loading), the type of abutment, microscopes or enlargement factors used for measurements, and the quantity and location of single (KREJICI) measurements. (Beschnidt & Strub, 1999)

Different techniques have been used to measure the marginal fit of restorations. Rinke, Huls, and Jahn (1995) utilized a stereomicroscope combined with a computer system to evaluate marginal gaps. (Bindl & Mörmann, 2005) Pelekanos, Koumanou, Koutayas, Zinelis, and Eliades (2009) mentioned several methods to measure marginal fit, including the use of low viscosity impression materials, profilometry, optical microscopy, and stereomicroscopy. In their study, they used computerized x-ray microtomography to measure the marginal fit of four groups made of four In-Ceram alumina core specimens (In-Ceram, Celay, Cerec inLab, and Wol-Ceram systems). One of the advantages of x-ray microtomography is that it is a non-destructive method that provides images of the internal structure of the specimen (in section form) and at the same time allows for a 3-D reconstruction of each selected position. They found that Wol-Ceram provided the best and Cerec inLab the second best marginal fit.

Marginal Fit Configurations

The fit of all-ceramic and metal-ceramic crowns has been studied. In addition, the effect of marginal finish line configuration such as chamfer and shoulder has been discussed. It was demonstrated that shoulder finish lines produce significantly less distortion in labial margins of metal-ceramic crowns than do chamfer finish lines (Tao & Han, 2009; Sulaiman, 1997). However, there is need of further investigation regarding the effect of the curvature of the abutment finish line on the marginal fit (Tao & Han, 2009).

As a consequence of the apical position of the lingual and labial gingival margin levels in relation to the interdental gingival margins, the tooth marginal finish line (after crown preparation is completed) will exhibit some degree of curvature. The curvature of the abutment finish line can change in various clinical situations. For example, when a clinical crown is short, the abutment finish line will likely be relatively flat. In contrast, elderly patients often exhibit physiologically age-related gingival recession; similarly, patients with a history of periodontal disease may have pathologic gingival recession. In these situations, the abutment finish lines of anterior teeth show a gradual curve, whereas with canines at the turning point of the dental arch, the labial gingival margin levels are more apical than usual, and the abutment finish lines may show a sharper curve (Tao & Han, 2009).

Tao and Han (2009) investigated the effect of finish line curvature on the marginal gaps of all-ceramic and metal ceramic crowns. They concluded that the

abutment finish line curvature had no significant effect on the marginal fit of all-ceramic crowns. However, they found a significant effect on the marginal fit of metal-ceramic crowns: increasing the curvature of the marginal finish line from one to five millimeters resulted in significantly larger labial and lingual marginal gaps . In addition, there were smaller marginal gaps on metal ceramic crown copings, when compared to all-ceramic crown copings. Tsitrou, Northeast, and Noort (2007) investigated the marginal fit of three margin designs (bevel, chamfer, shoulder) of resin composite crowns fabricated using the CEREC 3 system. They were trying to find if the application of a more conservative finish line would influence the marginal fit of CEREC restorations using this material. Two methods of measurement were used. One was the measurement of embedded and sectioned specimens, and the other was the measurement of the replica of the marginal gap. Tsitrou, Northeast and Noort (2007) concluded that the mean marginal gaps of resin composite crowns fabricated with the CEREC 3 system were within the range of clinical acceptance regardless of the finishing line prepared. Regarding the measurement technique, there was not a statistically significant different between the two methods.

In another study, Biscaro, Bo, Soattin, and Viogolo (2012) assessed invivo the marginal fit of single crowns produced using two CAD/CAM all-ceramic systems, in comparison to more traditional metal ceramic crowns. Thirty caries free and untreated vital teeth from five patients, in need of extractions for implant placement, were chosen. They fabricated ten metal ceramic crowns with porcelain occlusal surfaces for the control group and in two other groups CAD/CAM technology was used for the

fabrication of 20 zirconium-oxide-based ceramic single crowns. Then the teeth were extracted one month later. Marginal gaps were measured for each crown with a microscope at a magnification of 50x. On completion of microscopic evaluation, representative specimens from each group were prepared for ESEM evaluation. The results from ANOVA analysis revealed no quantitative difference between all groups. They concluded that zirconium-oxide-based ceramic CAD/CAM crowns demonstrated a similar and acceptable marginal fit when compared to more traditional metal ceramic crowns.

Summary

In the recent years new developments in computer technology and dental materials have led to improvements of dental CAD/CAM technology. In addition, dental restorations produced with computer assistance have become more common. Highly sophisticated in-office and laboratory CAD/CAM systems have been developed. Like for example a series of methods have been used to collect three-dimensional (3D) data of the prepared tooth from optical cameras to contact digitization and laser scanning. Replacement of conventional milling discs with a variety of diamond burs has resulted in major improvements in milling technology. Another vital factor has been the development of alumina and zirconia ceramic materials, which possess excellent machinability and physical strength. (Liu & Essig, 2008)

Most companies have access to dental CAD/CAM procedures either in dental practice or laboratory. Some benefits related with CAD/CAM generated dental restorations are: the access to new industrially prefabricated and controlled materials; an increase in quality and reproducibility and also data storage commensurate with a standardized chain of production; an improvement in precision and planning, as well as an increase in efficiency. As a result of continual developments in computer hardware and software, new methods of production and new treatment concepts are to be expected, which will enable an additional reduction in costs. (Beuer, Schweiger, & Edelhoff, 2004)

Some future technologies in CAD/CAM are the generative production methods, which in contrast to grinding technology do not work by subtracting, but rather by adding material. In the dental area there are some areas of application for which this technology is already applied. Another innovation are the 'laser sintering devices', which are used to produce crown and bridge frames from chrome cobalt alloys. Since the productivity with this new equipment is high, dental restorations can be produced very cost-effectively. Basically, geometries are conceivable with this technology that cannot be realized with grinding technology. (Beuer, Schweiger, & Edelhoff, 2004)

In spite of all the benefits of these new methods, the dentist's working procedures will have to be adapted to the methods of CAD/CAM and milling technology. These include appropriate tooth preparations with the creation of a continuous preparation margin, which is clearly recognizable to the scanner. Shoulderless preparations and parallel walls should be avoided. In addition, sharp incisor and occlusal edges are to be rounded. In addition, sharp edges cannot be milled precisely, because of the use of rounded grinders in the milling devices. A 360 degree shoulder or chamfer preparation is considered to be the appropriate marginal preparation geometries for CAD/CAM produced all-ceramic restorations. (Beuer, Schweiger, & Edelhoff, 2004) The goal is to achieved the best precision of fit, which have been reported to be 10-50 micrometers in the marginal area. (Reich, Wichmann, Nkenke, & Proeschel, 2005; Tinschert, Natt, Matsch, Spiekermann, & Anusavice, 2001; Bindl & Mörmann, 2005; Beuer, Schweiger, & Edelhoff, 2004)

There has been a variety of different studies about marginal fit of all-ceramic crowns, but not many have been performed related to Vitablocs Mark II, and none have been found related to the effect of marginal finish line configuration utilizing CEREC CAD/CAM-fabricated Vitablocs Mark II crowns. It is our goal to compare the effect of the curvature of the abutment finish line on the marginal fit utilizing Vitablocs Mark II. We want to know if an increase finish line curvature cause more marginal misfit in CAD/CAM crowns, when compared to a flat finish line configuration. Our null hypothesis is that there is not a difference in the marginal fit of CAD/CAM crowns with increasing finish line curvature.

MATERIALS AND METHODs

For this pilot study, three experimental groups were devised, with 1 specimen in each group:

- Group A – 0° marginal interproximal margin
- Group B – approx. 45° interproximal margin
- Group C – approx. 90° interproximal margin
-

3 metal master dies were prepared for scan and crown design following Ivoclar Vivadent, Inc. manufacturer's recommendations. These are:

- 0.8 -1mm uniform butt joint margin
- 1-1.5mm facial reduction
- 1.5mm lingual reduction
- 1.5-2mm of occlusal reduction

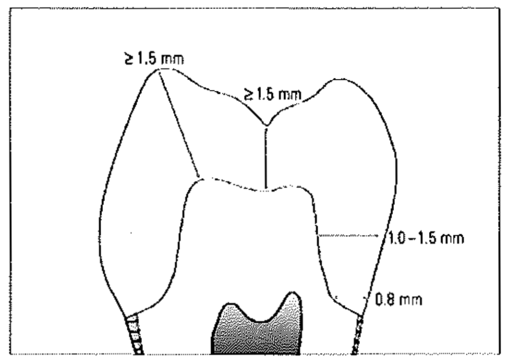


Figure 1

To prepare the master dies three Dentoform teeth #4 were used

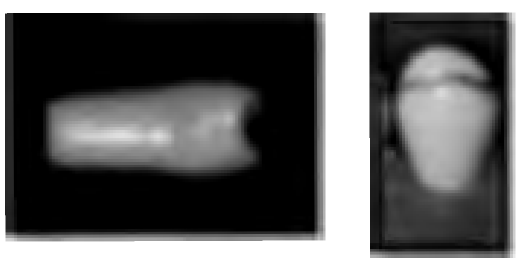


Figure 2

Three types of interproximal margins of 0°, 45°, and 90° were prepared for each crown in each dentoform tooth.

Each dentoform die was duplicated in GC pattern resin, sprued, invested with beauty cast material and casted, with Wiron 99 (Nickel-Chrome metal, free of beryllium) (Ni 65%, Cr 22.5%, Mo 9.5%, Nb, Si, Fe, Ce)

Then it was divested, de-sprued and polished

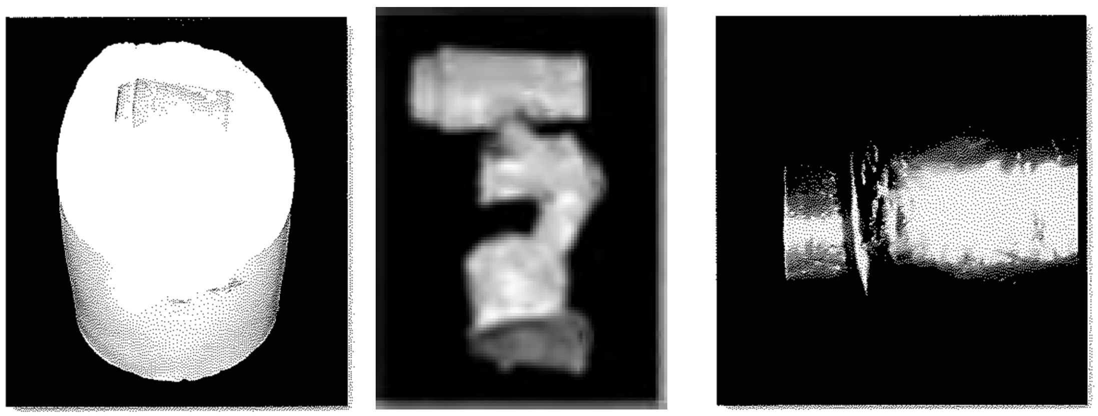
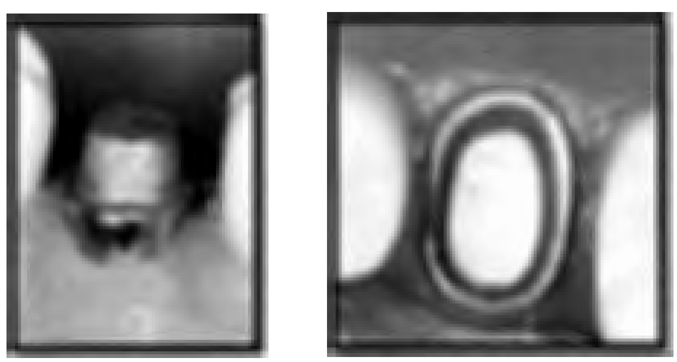


Figure 3

Retrieved master dies were adjusted to approximate the original gingival contours in the dentoform using metal polishing burs. Then each one was air abraded with Aluminum oxide 20 psi to a uniform surface.

Figure 4



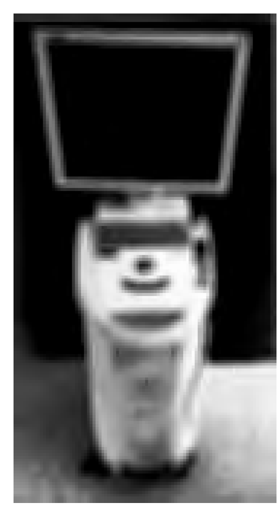


Figure 5

Each master die placed in the dentoform was sprayed with CEREC Optispray (Sirona Dental Systems, GmbH; Bensheim, Germany) and then scanned with an Omnicam (Sirona Dental Systems GmbH; Bensheim, Germany)

Omnicam is the newest version put out by Sirona (released 2013). Rather than a blue wavelength of light, the Omnicam uses a white light, which the company claims is more accurate and provides faster imaging acquisition.

- 0° interproximal margin

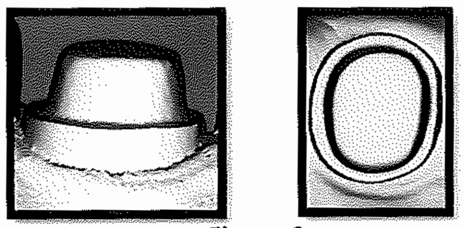


Figure 6

- 45° interproximal margin

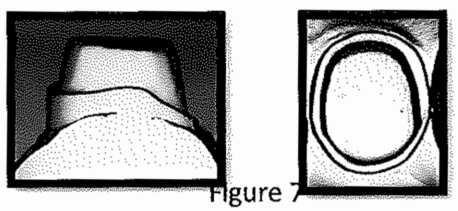


Figure 7

- 90° interproximal margin

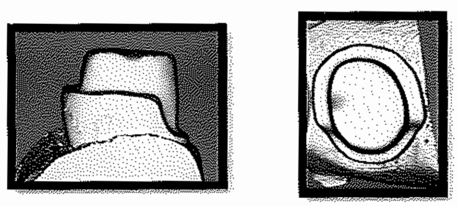


Figure 8

All restorations were designed with Sirona 4.3 software:

- 0° interproximal margin

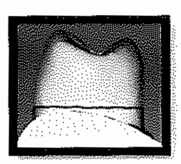


Figure 9

- 45° interprosimal margin

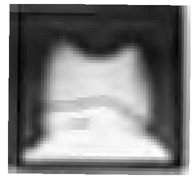


Figure 10

- 90° interproximal margin

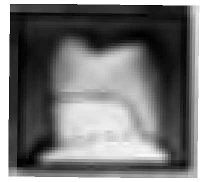


Figure 11

A crown for each specimen was milled in wax using the MCXL milling machine from Sirona

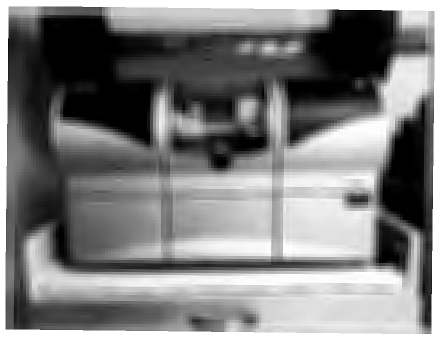


Figure 12

Each crown was tried on the respective metal master die

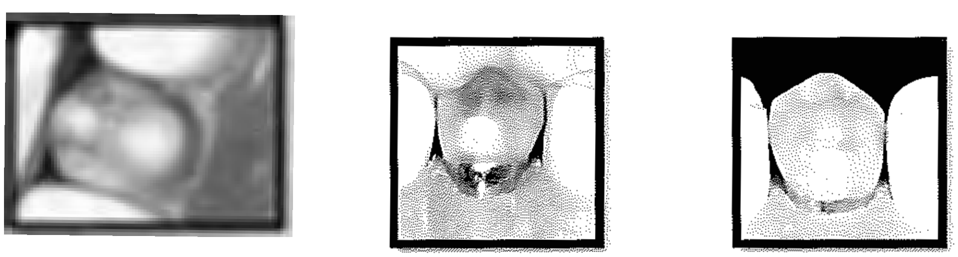


Figure 13

A seating index was fabricated to ensure that the crown remained fully seated on the die for measurements

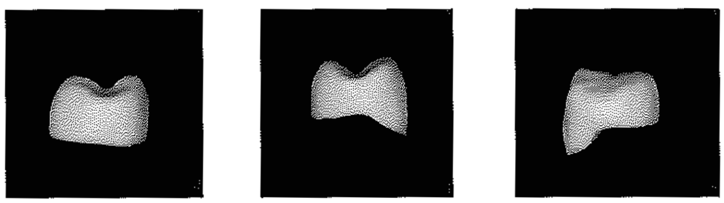
The overall measurement of the crown/die was used to fabricate a seating jig

The jig had four sides, which indexed the fixture on the KH 7700 Hirox 3D Digital Scanner

Figure 14

One ceramic crown for each group was milled

Figure 15



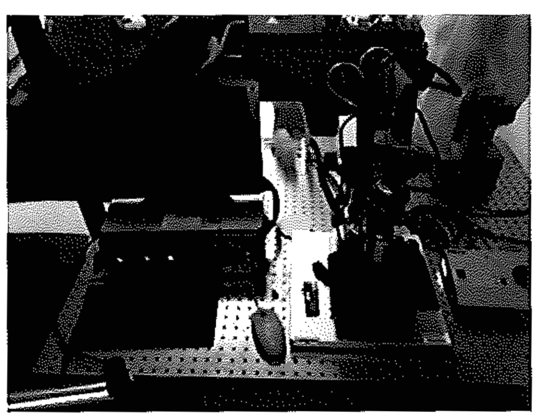
0° 45° 90°

The fit of the crowns was checked on the master die

The crown and die were positioned in the seating jig

The KH 7700 Hirox 3D Digital Scanner was used to measure the misfit

Figure 16

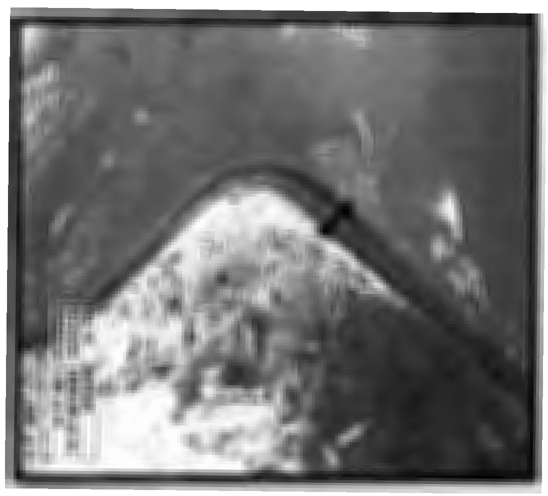


A grid on the screen of the microscope was developed, each square measured 1600μm. Three squares were used to perform the measurements.

Figure 17

Measurements were recorded from a selected point on the outer edge of the preparation to a point on the outer aspect of the restoration.

Figure 18



Thirty measurements were made at the mesial, distal, lingual and buccal side of the crowns (Total of 120 measurements per tooth) and each measurement was made in randomized order inside the established area of the grid.

The Hirox microscope automatically recorded the measurements in a CSV file

These pictures demonstrate the interproximal view of each tooth.

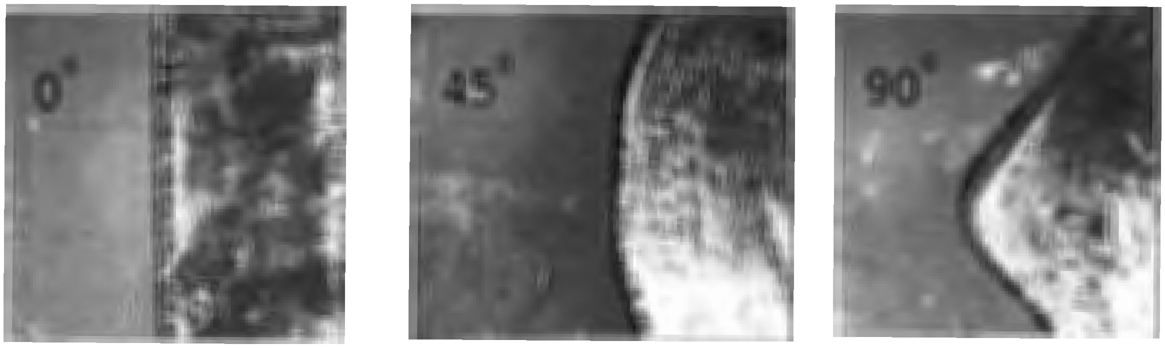


Figure 19

RESULTS

Means were calculated regarding the margin location (buccal/lingual, mesial/distal) (Figure #20 demonstrate measurements of each specimen) and the results demonstrated to be within the American Dental association requirements.

The total mean values of marginal misfit are shown in Graph #1. The analysis of the results of this pilot study demonstrated that the Zero degree finish line angle exhibited the lowest marginal misfit, and the 45-degree finish line exhibited the greatest.

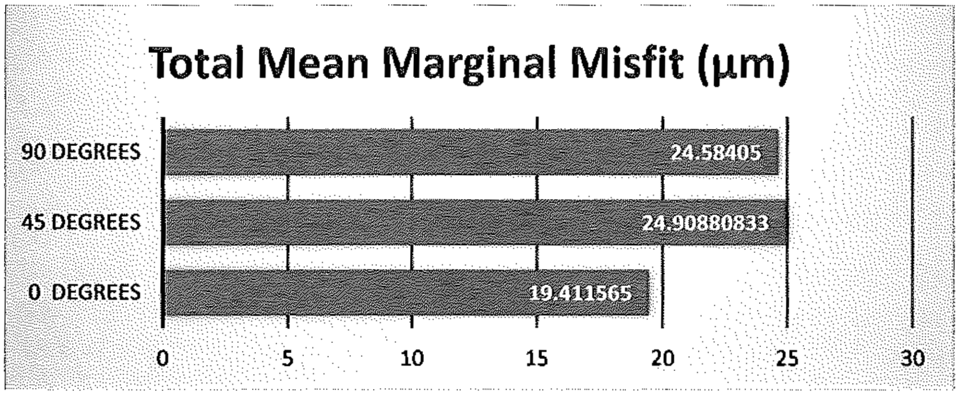
The mean marginal fit of all the crowns was 22.92 micrometers and the marginal misfit of each crown were: 0°: 19.41um, 45°: 24.90um, 90°: 24.58um.

The crown with a 45-degree finish line had the greatest misfit

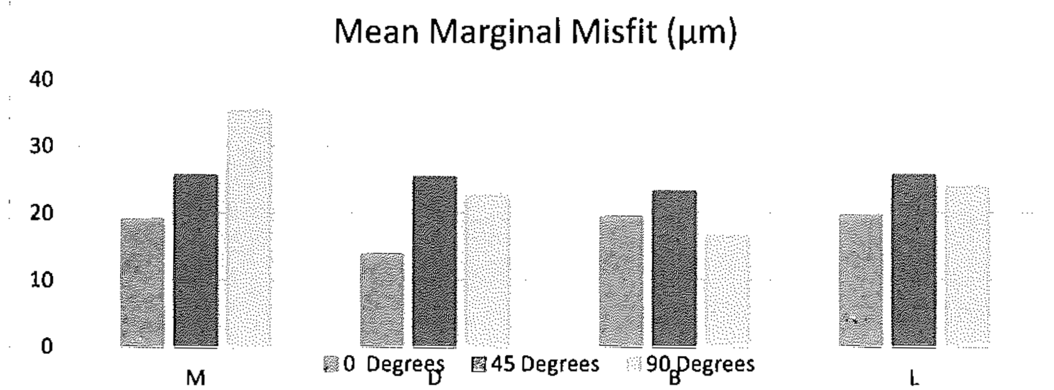
Graph #2 is showing the means of marginal fit at the mesial, distal, buccal, lingual area of each tooth. From the different marginal locations, the mesial area on every restoration exhibited the greatest misfit. Restorations with 45 and 90-degree finish line curvatures had the greatest misfit at the mesial and distal margins. The mean value of each location in the zero and 45-degree finish lines h

and the least variability

Graph #1



Graph #2



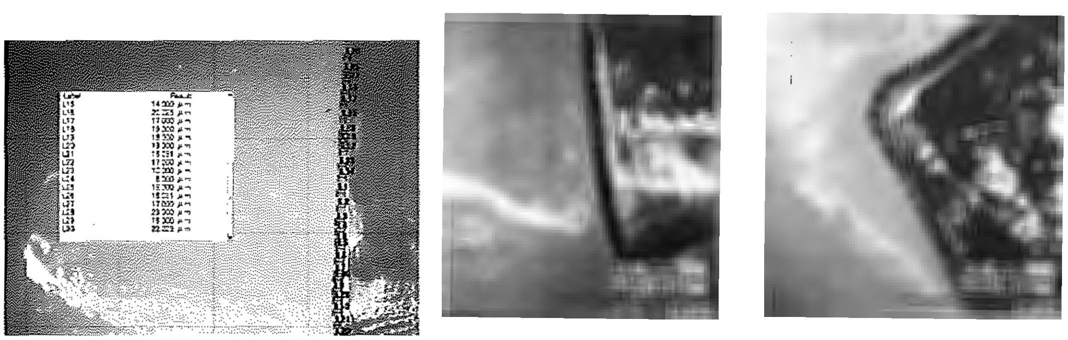


Figure 20: Picture on the left demonstrates the interproximal area of the 0-degree sample and the data obtained in a CVS file from the Hirox microscope. The picture in the middle demonstrates the lingual area of the 45-degreee samples with the measurements of the grid showed in the screen of the Hirox microscope. Picture on the right demonstrate measurements of the interproximal part of the 90-degree specimen.

DISCUSSION

According to this pilot study the null hypothesis that there is no difference in the marginal fit of CAD/CAM crowns with increasing finish line curvature could be rejected in the future. A study with at least eight specimens on each group should be performed in order to be able to perform a statistical analysis with a two way ANOVA test, with pairwise comparisons using Tukey's test comparing overall average marginal discrepancy. This amount of specimens and statistics will provide enough information to approve or reject the null hypothesis of this research study.

In this study, the marginal misfit between crown (made of Vitablocs Mark II) and metal master die were directly measured with the KH 7700 Hirox 3D Digital Scanner. The replica technique used to make the dies and the crowns are reliable noninvasive way that helps determine the adaptation of crown to tooth surface.

The goal in the design of this pilot-in vitro study was to investigate the potential effect of finish line curvature on marginal fit of all ceramic crown made of Vitablocs Mark II.

The results have demonstrated that the MCXL can mill Vitablocs Mark II ceramic crowns in accordance with the specifications of the American Dental Association. The data suggests that the interproximal finish line curvature had an effect on the marginal fit of the ceramic crowns. This may be due to the milling process, as related to the size and diameter of the burs, material, and orientation of the block. Also, the condition of the

burs after each single crown milling should be evaluated for potential deterioration and inability to mill the material at the same rate and efficacy.

Completion of this study is pending receipt of additional ceramic materials and burs.

Sample size of eight specimens will be used per group. Statistical analysis will be performed and the null hypothesis tested.

Future studies should examine the effect of bur type and diameter on the marginal fit. The effect of the physical characteristics of the material when milled should also be evaluated.

Because this study is investigating only one all ceramic CAD/CAM crown system and material, the external validity of the results of this system for crowns of other systems is limited.

CONCLUSIONS

Within the limitations of this in vitro pilot study the following conclusion was drawn:

1- The 45 and 90-degree interproximal finish line curvatures resulted in greater misfit in all ceramic CAD/CAM crowns. However, the data demonstrated measurements were within the American Dental Association specifications.

APPENDIX

SPECIMEN COLLECTION DATA SHEET

Misfit measurements for the 0° interproximal margin

Buccal

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	16.279	um	---
L2	36.014	um	---
L3	41.195	um	---
L4	34	um	---
L5	33	um	---
L6	31	um	---
L7	31.016	um	---
L8	28.16	um	---
L9	30.067	um	---
L10	29.017	um	---
L11	22	um	---
L12	38.013	um	---
L13	30.067	um	---
L14	29.017	um	---
L15	29	um	---
L16	32.016	um	---
L17	25	um	---
L18	24	um	---
L19	22	um	---
L20	11	um	---
L21	14.142	um	---
L22	14	um	---
L23	18.028	um	---
L24	18	um	---
L25	21.024	um	---
L26	25.02	um	---
L27	17.029	um	---
L28	18	um	---
L29	19.105	um	---
L30	24	um	---

Distal

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	19	um	---
L2	16	um	---
L3	18.028	um	---
L4	13	um	---
L5	14.036	um	---
L6	14.036	um	---
L7	12	um	---
L8	13.038	um	---
L9	14.036	um	---
L10	14.036	um	---
L11	16.031	um	---
L12	15	um	---
L13	14.036	um	---
L14	13	um	---
L15	13	um	---
L16	11.045	um	---
L17	11.045	um	---
L18	14.036	um	---
L19	12	um	---
L20	10.05	um	---
L21	13	um	---
L22	15	um	---
L23	13	um	---
L24	14.142	um	---
L25	11	um	---
L26	12	um	---
L27	14	um	---
L28	14	um	---
L29	12	um	---
L30	17.117	um	---

Lingual

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	22.023	um	---
L2	22	um	---
L3	23	um	---
L4	23.022	um	---
L5	23.022	um	---
L6	24	um	---
L7	25.02	um	---
L8	24.083	um	---
L9	24	um	---
L10	24	um	---
L11	26	um	---
L12	21	um	---
L13	21	um	---
L14	21.024	um	---
L15	14	um	---
L16	20.025	um	---
L17	17	um	---
L18	19	um	---
L19	18	um	---
L20	13	um	---
L21	16.031	um	---
L22	17	um	---
L23	10	um	---
L24	8	um	---
L25	18	um	---
L26	16.031	um	---
L27	17	um	---
L28	23	um	---
L29	16	um	---
L30	22.023	um	---

Mesial

2D Measuring Data	Column1	ColumnL2	Column3
Label	Result	Unit	Ratio
L1	31	um	---
L2	26	um	---
L3	25.02	um	---
L4	19	um	---
L5	22	um	---
L6	22	um	---
L7	29.017	um	---
L8	30	um	---
L9	22	um	---
L10	21.024	um	---
L11	13	um	---
L12	6.083	um	---
L13	8.246	um	---
L14	8	um	---
L15	16.031	um	---
L16	16.031	um	---
L17	13.038	um	---
L18	12	um	---
L19	10	um	---
L20	17.029	um	---
L21	20	um	---
L22	19	um	---
L23	24.021	um	---
L24	21.024	um	---
L25	23.087	um	---
L26	17.263	um	---
L27	22	um	---
L28	20.224	um	---
L29	20.025	um	---
L30	17	um	---

Misfit measurements for the 45° interproximal margin

Buccal

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	36	um	---
L2	28	um	---
L3	20	um	---
L4	41	um	---
L5	37.014	um	---
L6	29.12	um	---
L7	29.614	um	---
L8	31	um	---
L9	23.087	um	---
L10	14.036	um	---
L11	17.464	um	---
L12	13	um	---
L13	28	um	---
L14	35	um	---
L15	12.649	um	---
L16	21	um	---
L17	20.025	um	---
L18	13.038	um	---
L19	15	um	---
L20	6	um	---
L21	15.033	um	---
L22	11	um	---
L23	22	um	---
L24	30.067	um	---
L25	33.015	um	---
L26	26.173	um	---
L27	28.018	um	---
L28	28	um	---
L29	18.028	um	---
L30	13	um	---

Distal

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	14	um	---
L2	21.024	um	---
L3	19	um	---
L4	14.866	um	---
L5	20.224	um	---
L6	18.439	um	---
L7	22.361	um	---
L8	23.324	um	---
L9	30.364	um	---
L10	34.54	um	---
L11	32.65	um	---
L12	41.231	um	---
L13	29	um	---
L14	23.537	um	---
L15	31.016	um	---
L16	24.187	um	---
L17	38.013	um	---
L18	44.553	um	---
L19	28.653	um	---
L20	19.105	um	---
L21	20.1	um	---
L22	20.396	um	---
L23	17	um	---
L24	15	um	---
L25	21.095	um	---
L26	20.025	um	---
L27	33.377	um	---
L28	21.378	um	---
L29	23.409	um	---
L30	36.249	um	---

Lingual

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	48.042	um	---
L2	32.249	um	---
L3	34	um	---
L4	39.217	um	---
L5	30.017	um	---
L6	41.012	um	---
L7	34	um	---
L8	31	um	---
L9	21.213	um	---
L10	21.095	um	---
L11	20	um	---
L12	20	um	---
L13	21	um	---
L14	24	um	---
L15	20.616	um	---
L16	17.205	um	---
L17	21.84	um	---
L18	19.925	um	---
L19	19.235	um	---
L20	23	um	---
L21	21.213	um	---
L22	29.155	um	---
L23	27.893	um	---
L24	18.028	um	---
L25	14.765	um	---
L26	23.087	um	---
L27	23.409	um	---
L28	21.024	um	---
L29	28.018	um	---
L30	23.022	um	---

Mesial

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	34.366	um	---
L2	29.411	um	---
L3	22	um	---
L4	27.203	um	---
L5	19.647	um	---
L6	21.954	um	---
L7	51.894	um	---
L8	39.357	um	---
L9	28.792	um	---
L10	39.825	um	---
L11	57.775	um	---
L12	34.205	um	---
L13	35.468	um	---
L14	27.731	um	---
L15	27.074	um	---
L16	24.698	um	---
L17	22	um	---
L18	13.153	um	---
L19	8	um	---
L20	14.318	um	---
L21	16.125	um	---
L22	16	um	---
L23	25.08	um	---
L24	25.942	um	---
L25	15.033	um	---
L26	18.385	um	---
L27	18	um	---
L28	17.464	um	---
L29	14	um	---
L30	29.155	um	---

Misfit measurements for the 90° interproximal margin

Buccal

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	29.069	um	---
L2	6	um	---
L3	6	um	---
L4	5	um	---
L5	8.062	um	---
L6	16	um	---
L7	17	um	---
L8	25.495	um	---
L9	23	um	---
L10	16.125	um	---
L11	18	um	---
L12	21.024	um	---
L13	19.925	um	---
L14	17.029	um	---
L15	24	um	---
L16	21.024	um	---
L17	25	um	---
L18	9.22	um	---
L19	11	um	---
L20	10	um	---
L21	4	um	---
L22	12.042	um	---
L23	16.125	um	---
L24	16	um	---
L25	25.318	um	---
L26	29.428	um	---
L27	24.187	um	---
L28	18	um	---
L29	12	um	---
L30	12.369	um	---

Distal

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	35.468	um	---
L2	38.949	um	---
L3	48.795	um	---
L4	28.792	um	---
L5	35.355	um	---
L6	34.828	um	---
L7	37.537	um	---
L8	36.401	um	---
L9	35.609	um	---
L10	12.166	um	---
L11	15.133	um	---
L12	18.788	um	---
L13	16.155	um	---
L14	12.083	um	---
L15	10.817	um	---
L16	10.296	um	---
L17	9.434	um	---
L18	13.601	um	---
L19	14.213	um	---
L20	19.723	um	---
L21	15.556	um	---
L22	18.385	um	---
L23	2.828	um	---
L24	14.142	um	---
L25	10.63	um	---
L26	13.601	um	---
L27	12.083	um	---
L28	36.069	um	---
L29	34.409	um	---
L30	34.655	um	---

Lingual

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	28.071	um	---
L2	27.019	um	---
L3	30.017	um	---
L4	26	um	---
L5	27	um	---
L6	28	um	---
L7	25.02	um	---
L8	18.028	um	---
L9	10	um	---
L10	6	um	---
L11	18	um	---
L12	19	um	---
L13	20	um	---
L14	36.014	um	---
L15	24.021	um	---
L16	27.019	um	---
L17	29	um	---
L18	33	um	---
L19	17.029	um	---
L20	25.02	um	---
L21	23	um	---
L22	23.022	um	---
L23	21.024	um	---
L24	26.019	um	---
L25	30	um	---
L26	29.017	um	---
L27	32.062	um	---
L28	8.062	um	---
L29	20.025	um	---
L30	31.016	um	---

Mesial

2D Measuring Data	Column1	Column2	Column3
Label	Result	Unit	Ratio
L1	43.105	um	---
L2	45.177	um	---
L3	34.785	um	---
L4	33.242	um	---
L5	30.414	um	---
L6	32.757	um	---
L7	34.205	um	---
L8	38.275	um	---
L9	39.357	um	---
L10	34.059	um	---
L11	31.385	um	---
L12	30.463	um	---
L13	35.355	um	---
L14	33.242	um	---
L15	31.305	um	---
L16	35.693	um	---
L17	52.01	um	---
L18	37.363	um	---
L19	40.497	um	---
L20	37.014	um	---
L21	31.765	um	---
L22	30.871	um	---
L23	28.178	um	---
L24	42.802	um	---
L25	32.28	um	---
L26	34.482	um	---
L27	31.145	um	---
L28	33.015	um	---
L29	26.926	um	---
L30	38.471	um	---

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